Dam Safety Risk Based Profile System
Summary Table

Dam Name: _____ National ID: _____ Rating Official: _____ Date of Rating: _____

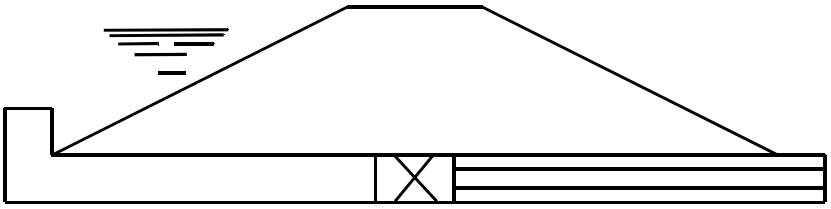
Loading Condition	**A. Load Factor**	**B. Response Factor**	**C. Failure Index**	**D. Loss of Life Factor**	**E. Risk Index**	**F. Total PAR**	**G. Socio-Economic Index**
1. Static	1	Factor = _____ (From Worksheet A - Emb. Dams, or Worksheet B - Concrete Dams)	Index = _____ (Load Factor x Response Factor) (300 points maximum)	Factor = ____ (From Worksheet H)	Index = _____ (Failure Index x Loss of Life Factor)	_____ (Wrksht. H)	Index = _____ (Failure Index) x (Total PAR/1000)
2. Hydrologic			Index = _____ (From Worksheet C) (300 points maximum)	Factor = ____ (From Worksheet H)	Index = _____ (Failure Index x Loss of Life Factor)	_____ (Wrksht. H)	Index = _____ (Failure Index) x (Total PAR/1000)
3. Seismic	Factor = ____ (From Worksheet D)	Factor = _____ (From Worksheet E - Emb. Dams, or Worksheet F - Concrete Dams)	Index = _____ (Load Factor x Response Factor) (300 points maximum)	Factor = ____ (From Worksheet H)	Index = _____ (Failure Index x Loss of Life Factor)	_____ (Wrksht. H)	Index = _____ (Failure Index) x (Total PAR/1000)
4. Operations, Maintenance, and Safety			Index = _____ (From Worksheet G) (100 points maximum)	0.1	Index = _____ (Failure Index x Loss of Life Factor)		
5. Totals							

A Summary Table is to be completed for each dam and dike that retains the reservoir.

Dam Safety Risk Based Profile System - **Worksheet A - Static Response Factor for Embankment Dams**

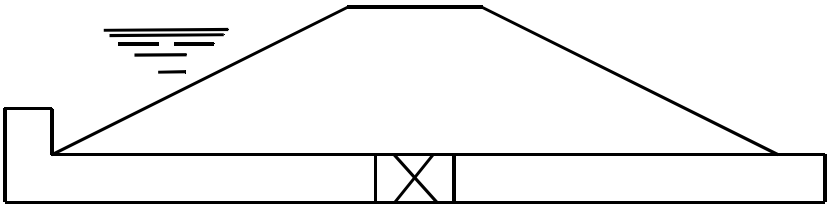
Outlet works (76 points) - Only score dams with outlet works through embankment. Do not score dams with outlet works through a tunnel or no outlet works.	**Reservoir filling history (75 points)** Note: hydraulic height = streambed to maximum controllable water surface)	**Seepage and Deformation (79 points)**
Check all that apply: ‘ No downstream filters or filter zone around conduit. ‘ Outlet conduit located in deep (greater than height of conduit) and narrow trench (cutslopes steeper than 2:1) in soil or rock, particularly with vertical or irregular sides or close to abutment slope. ‘ Outlet pipe of material prone to corrosion in badly deteriorated condition or of unknown condition; masonry construction. ‘ Poor conduit geometry such as overhangs; poor haunch support; seepage cutoff collars or other features that make compaction of the backfill around the conduit difficult; poorly compacted backfill ‘ Open cracks in the outlet conduit, open joints, weep holes, seepage from cracks/joints into conduit. ‘ Conduit founded on soil or highly compressive/expansive rock.	Identify which one applies: 75 points Reservoir never filled to 50 % of hydraulic height 50 points Reservoir filled 50 % to 75 % of hydraulic height 25 points Reservoir filled 75 % to 90 % of hydraulic height 10 points Reservoir filled 90 % to 95 % of hydraulic height 5 points Reservoir filled 95% to 100% of hydraulic height 0 points Reservoir $\geq$ 100% of hydraulic height	Check all that apply: Critical: ‘ Seepage carrying fines (excluding benign sandboils). ‘ Seepage increasing at same reservoir elevation. Significant: ‘ Large amount of seepage. ‘ Slope movement (longitudinal cracking, offsets). ‘ Sinkholes, depressions. ‘ Poor toe drains (potential conduit for piping). ‘ Poor conditions at crest [badly eroded crest area, trees/rodent holes within 10' (vert.) of crest, serious displacements, sinkholes, transverse cracking > 1 ft. depth]. ‘ Abnormally high artesian pressures beneath D/S foundation area. ‘ Inadequate slope protection
Scoring: ___ items x 4 pts. = _____ (19 pts. max) Multiply this by type factor (see reverse) to obtain Outlet Works Score (max. score = 76)		Scoring: 79 points Either of the Critical items 40 points Five Significant items 30 points Four Significant items 20 points Three Significant items 10 points Two Significant item 5 points One Significant item
Outlet Works Score: _____	Reservoir Filling Score: _____	Seepage and Deformation Score: _____

OUTLET WORKS
TYPE FACTORS



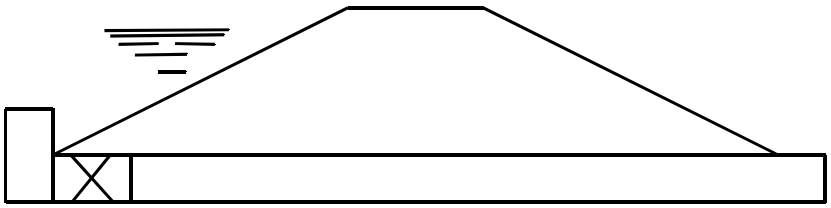
TYPE FACTOR = 1

CASE 1 – Control in middle of conduit, with open access to middle
Gradient in/out conduit = Medium
Access to inspect & repair = FREQUENT



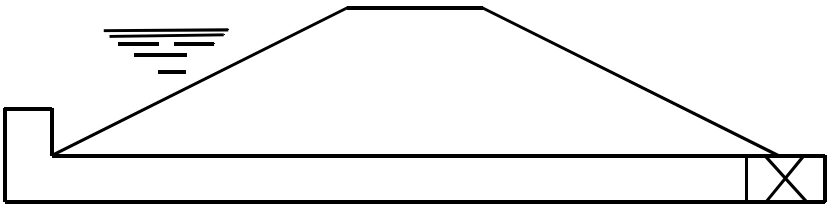
TYPE FACTOR = 2

CASE 2 – Control in middle of conduit
Gradient in/out conduit = Medium
Access to inspect & repair = OCCASIONAL



TYPE FACTOR = 3

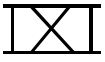
CASE 3 – Control at upstream end of conduit
Gradient in/out conduit = High
Access to inspect & repair = OCCASIONAL



TYPE FACTOR = 4

CASE 4 – Control at downstream end of conduit
Gradient in/out conduit = High
Access to inspect & repair = SELDOM/NEVER

Notation :

 = Control Location

Dam Safety Risk Based Profile System - **Worksheet A - Static Response Factor for Embankment Dams** (continued)

Embankment Design and Construction (28 points)	**Foundation Geology (18pts)**	**Embankment Monitoring (24 points)**
Check all that apply: ‘ No filters for core or soil foundation or incompatibility between zones. ‘ No foundation treatment on open jointed hard rock foundation (slush grout, dental concrete). ‘ No drainage layers. ‘ Erodible core material (predominantly sandy, silty, or dispersive material). ‘ No foundation cutoff of permeable foundation. ‘ Poorly constructed dam (poor density of earthfill, hydraulic fill) ‘ No ability to evacuate reservoir	Check all that apply: ‘ Highly fractured rock and/or large open joints (including faults and shears) in contact with core ‘ Coarse grained soil foundation. ‘ Presence of weak layers/conditions leading to potential embankment instability. ‘ Erodible soils (predominantly sandy or silty material) or weakly cemented erodible rock. ‘ Rock prone to solutioning (gypsum). ‘ Reservoir prone to large landslides that could cause overtopping.	Check all that apply: ‘ No instruments at dam or instruments not monitored (excluding surficial measurement points). ‘ No formalized schedule for monitoring of instruments. ‘ Instrument readings not evaluated. ‘ Instrument readings changing unexpectedly. ‘ Instruments not automated. ‘ Visual inspection less frequent than once per week. ‘ Visual inspection less frequent than once per month. ‘ Poor ability to inspect downstream groins and/or toe
Scoring: 4 points for each item (28 points maximum)	Scoring: 3 points for each item	Scoring: 3 points for each item
Embankment Design and Construction Score: _____	Foundation Geology Score: _____	Embankment Monitoring Score: _____

Total Static Response Factor for embankment dams = _____ (sum of 6 scores from above)

Place this value also in the Summary Table on page 1, cell B1.

Dam Safety Risk Based Profile System - **Worksheet B - Static Response Factor for Concrete Dams**

Reservoir filling history (60 points) Note: hydraulic height = streambed to maximum controllable water surface)	**Foundation/Geology (80 points)**	**Existing Condition of Concrete Dam (60 points)**
Identify which one applies: 60 points Reservoir never filled to 50 % of hydraulic height 40 points Reservoir filled 50 % to 75 % of hydraulic height 20 points Reservoir filled 75 % to 90 % of hydraulic height 10 points Reservoir filled 90 % to 95 % of hydraulic height 0 points Reservoir filled 95% to 100% or more of hydraulic height	Check all that apply: Critical: ‘ Foundation analyses for static loads show foundation instability (factor of safety < 1) ‘ Indications of foundation materials being carried by seepage Significant: ‘ No documentation of analysis of foundation for static loads or analyses show stability less than desired (1 < factor of safety < 3) ‘ Potential failure planes are observed, or erodible soils, weakly cemented erodible rock, or rock prone to solutioning are within foundation ‘ No provisions for foundation drainage or drains not functioning ‘ Rockfalls at dam or large landslides in reservoir	Check all that apply: ‘ Excessive amount of seepage at lift lines ‘ Excessive cracking or deterioration from freeze/thaw, AAR, or sulfate attack ‘ Indications of unacceptable deformations or differential movements
	Scoring: 20 points for each “critical” item 10 points for each “significant” item	Scoring: 20 points for each item
Reservoir Filling Score: _____	Foundation/Geology Score: _____	Existing Condition Score: _____

Dam Safety Risk Based Profile System - **Worksheet B - Static Response Factor for Concrete Dams** (continued)

Dam Design and Construction (70 points)	**Monitoring (30 points)**
Check all that apply: Critical: ‘ Analyses of the dam for static loads not considered state-of-the-art (i.e., improper uplift considerations) or show instability of the dam (factor of safety < 1) Significant: ‘ No documentation of analysis of dam for static loads or analyses show factor of safety less than desired (1 < factor of safety < 2) ‘ No formed drains (doesn’t apply to buttress dams) ‘ Low strength concrete used ‘ No or poor concrete temperature control used during construction ‘ No provisions for concrete expansion and contraction or contraction joints are not keyed	Check all that apply: Critical: ‘ No monitoring at dam or established monitoring program not being followed OR ‘ Recent monitoring results show unexpected behavior Significant: ‘ Visual or instrumented monitoring is performed erratically ‘ Monitoring results are not regularly evaluated
Scoring: 20 points for each “critical” item 10 points for each “significant” item	Scoring: 20 points for either “critical” item 5 points for each “significant” item
Dam Design and Construction Score: _____	Monitoring Score: _____

Total Static Response Factor for Concrete Dam = _____ (sum of 5 scores from above)
Place this value also in the Summary Table on page 1, cell B1.

Note: Any structural modifications or other actions taken at the dam to remove, treat, or otherwise prevent the potential deficiency from becoming a problem will preclude the need for checking the box(es) associated with that deficiency.

Dam Safety Risk Based Profile System - **Worksheet C - Hydrologic Failure Index**

Estimated 100-year Flood Peak _____ ft^3/s Estimated 100-year Flood Volume _____acre-feet Drainage Basin Area _____ square miles

Design Spillway Capacity _____ ft^3/s Surcharge Storage _____ acre-feet (spillway crest or top of gates to design max. water surface)
(Capacity of deteriorated/damaged structures should
be reduced to the flow capacity which can safely be passed)

Table 1: Design Spillway Capacity	Basic Score A*
Spillway capacity is less than the peak of the 100-year flood.	50
Spillway capacity is between 1 and 2 times the peak of the 100-year flood	25
Spillway capacity is between 2 and 3 times the peak of the 100-year flood	10
Spillway capacity is between 3 and 4 times the peak of the 100-year flood	5
Spillway capacity is greater than 4 times the peak of the 100-year flood	2
Dam safely accommodates all current PMF's	0

* Select the lowest applicable score

Table 2: Drainage Basin Size	Adjustment Factor F1
Less than 50 square miles	2.0
50 to 100 square miles	1.7
100-1000 square miles	1.4
Greater than 1000 square miles	1.0

Table 3: Flood Storage*	Basic Score B
Flood control/surcharge capacity is less than 50% of the 100-year flood volume	25
Flood control/surcharge capacity is between 50% and 100% of the 100-year flood volume	15
Flood control/surcharge capacity is 1 to 2 times the 100-year flood volume	7
Flood control/surcharge capacity is 2 to 3 times the 100-year flood volume	3
Flood control/surcharge capacity is 3 or more times the 100-year flood volume	1
Volume of the 100-year flood is unknown	20
Dam safely accommodates all current PMF's	0

* Based on design maximum water surface elevation

Table 4: Snowmelt Influence	Adjustment Factor F2
No 100-year flood hydrograph. Volume is estimated from TP-40 rainfall data and snowmelt would be the majority of the volume	2.0
No 100-year flood hydrograph. Volume is estimated from TP-40 rainfall data and snowmelt would be a significant contribution	1.5
No 100-year flood hydrograph. Volume is estimated from TP-40 rainfall data and snowmelt would be a minor contribution	1.2
Snowmelt makes no contribution to the flood volume	1.0
100-year flood hydrograph includes snowmelt contribution	1.0

Table 5: Type of Dam	Adjustment Factor F3
Embankment dam with thin or non-plastic core	2.0
Embankment dam with wide plastic core	1.7
Concrete dam on soil foundation (diversion dam)	1.5
Thin concrete arch or buttress dam	1.0
Embankment dam with overtopping protection	.8
Concrete gravity dam on rock foundation	.5

Basic Score A (Table 1) _____ (1)

Basic Score B (Table 3) _____ (4)

Factor F1 (Table 2) _____ (2)

Factor F2 (Table 4) _____ (5)

Factor F3 (Table 5) _____ (8)

Peak Flow Score [(1) times (2)] _____ (3)

Storage Volume Score [(4) times (5)] _____ (6)

Flood Routing Score [(3) plus (6)] _____ (7)

Final Hydrologic Failure Index [(7) times (8)] _____ (Place this value on page 1, cell C2)

Dam Safety Risk Based Profile System - **Worksheet D - Seismic Load Factor**

The USGS NEHRP map and the following table are used to calculate the seismic load factor (or multiplier) for the peak horizontal ground acceleration for the site. Place the factor obtained below in Cell A3 in the Summary Table on page 1.

Peak Ground Acceleration (PGA) from NEHRP	PGA<.1g	.1g<PGA<.2g	.2g<PGA<.4g	.4g<PGA<.6g	PGA>.6g
Seismic Load Factor	0	.15	.3	.65	1.0

To determine the NEHRP site acceleration, go to the following internet address:

http://geohazards.cr.usgs.gov/eq/html/lookup.shtml

Utilize the "SEISMIC HAZARD: Hazard by latitude longitude" to find site acceleration. Insert the latitude and longitude of the dam in the box and hit the "Submit Query" button (remember to input the longitude as a negative number). From the table that appears next, use the "2% in 50 year" column of data and the value in the row labeled "PGA." Don't be surprised if there are delays in having the PGA information appear. Connections to the USGS site can sometimes be slow.

If the latitude and longitude of the dam is unknown, go to the following internet address:

http://www.census.gov/cgi-bin/gazetteer-tbl?

Enter the name of the nearest town and state in the boxes provided, and hit the "Search" button. Hit "Map" on the "Browse the Tiger Map of the Area" line and locate the dam on the map (zoom out if necessary). Place the cursor over the dam and click the mouse button to center the map on the dam. The latitude and longitude of the map center are reported below the map. Round off to the nearest tenth.

Another source for the latitude and longitude of Bureau of Reclamation Dams is the DSIS database.

Dam Safety Risk Based Profile System - **Worksheet E - Seismic Response Factor for Embankment Dams**

Liquefaction Analysis Conducted: Yes_____ No _____ Known Liquefaction Problem: Yes _____ No _____

Embankment Fill Type: Compacted _____ Non-compacted _____ Foundation Type Beneath Slopes: Alluvium, Lacustrian, Loess _____
Bedrock or Clay _____

Amount of Normal Freeboard: _____ Dam Height Above Streambed: _____ Amount of Freeboard as a Percent of Dam Height: _____

Dam Includes Defensive Design Features: Yes _____ No _____ **Seismic Response Factor** (from 16 choices below): _____
(Place this value also in Cell B3 in the Summary Table on page 1)

A	liquefaction analysis done liquefaction analysis not done	go to B go to C	I	freeboard less than 25% of dam height freeboard 25% to 50% of dam height freeboard greater than 50% of dam height	score 150 score 75 score 10
B	foundation or embankment liquefies and flow slide likely, or remediation not adequate foundation or embankment does not liquefy or flow slide not likely, or remediation adequate	go to D go to E	J	freeboard less than 25% of dam height freeboard 25% to 50% of dam height freeboard greater than 50% of dam height	score 300 score 150 score 50
C	foundation could liquefy if loose (alluvium, lacustrian, loess etc.) foundation cannot liquefy (bedrock, highly clayey, etc.)	go to F go to G	K	dam designed with crack-stopping filters dam not designed with crack-stopping filters	score 10 score 50
D	embankment not liquefiable embankment liquefiable	go to I go to J	L	freeboard less than 25% of dam height freeboard 25% to 50% of dam height freeboard greater than 50% of dam height	score 100 score 50 score 10
E	freeboard less than 15 feet freeboard greater than or equal to 15 feet	go to K go to P	M	freeboard less than 25% of dam height freeboard 25% to 50% of dam height freeboard greater than 50% of dam height	score 200 score 100 score 25
F	compacted fill embankment uncompacted fill embankment	go to L go to M	N	dam designed with crack-stopping filters dam not designed with crack-stopping filters	score 10 score 50

G	compacted fill embankment	go to H	O	freeboard less than 25% of dam height	score 175
	uncompacted fill embankment	go to O		freeboard 25% to 50% of dam height	score 75
				freeboard greater than 50% of dam height	score 15
H	freeboard less than 15 feet	go to N	P	dam designed with crack-stopping filters	score 5
	freeboard greater than or equal to 15 feet	go to P		no filter protection or dam has other design weaknesses	score 25

Dam Safety Risk Based Profile System - **Worksheet F - Seismic Response Factor for Concrete Dams**

Foundation/Geology (140 points)	**Dam Design and Construction (100 points)**	**Existing Condition of Concrete Dam (60 points)**
Check all that apply: Critical: ‘ Foundation analyses for seismic loads show foundation instability (factor of safety < 1) Significant: ‘ Indications of foundation materials being carried by seepage ‘ No documentation of analysis of foundation for seismic loads ‘ Potential failure planes are observed, or erodible soils, weakly cemented erodible rock, or rock prone to solutioning are within foundation ‘ No provisions for foundation drainage or drains not functioning ‘ Rockfalls at dam or large landslides in reservoir	Check all that apply: Critical: ‘ Analyses of the dam for seismic loads not considered state-of-the-art, show instability of the dam (factor of safety < 1), or show excessive tensile stresses across the cross-section of the dam Significant: ‘ No documentation of analysis of dam for seismic loads ‘ Low strength concrete used ‘ No provisions for concrete expansion and contraction or contraction joints are not keyed	Check all that apply: ‘ Excessive amount of seepage at lift lines ‘ Excessive cracking or deterioration from freeze/thaw, AAR, or sulfate attack ‘ Indications of unacceptable deformations or differential movements
Scoring: 40 points for each “critical” item 20 points for each “significant” item	Scoring: 40 points for each “critical” item 20 points for each “significant” item	Scoring: 20 points for each item
Foundation/Geology Score: _____	Dam Design and Construction Score: _____	Existing Condition Score: _____

Total Seismic Response Factor for Concrete Dam = _____ (sum of 3 scores from above)
Place this value also in the Summary Table on page 1, cell B3.

Note: Any structural modifications or other actions taken at the dam to remove, treat, or otherwise prevent the potential deficiency from becoming a problem will preclude the need for checking the box(es) associated with that deficiency

Dam Safety Risk Based Profile System - **Worksheet G - Operations, Maintenance, and Safety**

Check all that apply:

Tier 1:

- One spillway or outlet gate has a discharge capacity (with a normal reservoir water surface) greater than the safe downstream channel capacity
- The spillway or outlet works are not operational or operate only at a greatly reduced capacity
- The dam is not operated in accordance with the Standing Operating Procedures
- Hazardous conditions exist for the dam operations staff in performing their normal duties
- Fencing, guardrails, or signs are inadequate to warn the public of potential safety hazards
- Spillway is subject to substantial erosion/headcutting during operation (substantial damage is interpreted as being able to envision a reasonable potential to loose the control section in one or two flood events that lead to spillway discharge)

Tier 2:

- An evaluation of the spillway or outlet gates and hoist systems indicates a potential structural or operational problem
- No provisions are made for auxiliary power to operate the gates or valves
- Woody vegetation is growing on or adjacent to the dam or appurtenant structures
- Rodent holes are prevalent in the dam or adjacent foundation

Scoring:

80 points Three or more Tier 1 items
50 points Two Tier 1 items
25 points One Tier 1 item
5 points for each Tier 2 item

Operations, Maintenance, and Safety Failure Index: _____ (Place this value also in the Summary Table on page 1, cell C4)

Dam Safety Risk Based Profile System - **Worksheet H - Loss of Life Factors**

Life Loss Weighting Factor Calculation

Distance Downstream (Dist. D/S)	PAR	Percent Moderate Severity (%PAR_Mod)	Warning Time Category	Rate Ratio For Mod. Severity (R_Ratio Mod)	Rate Ratio For Low Severity (R_Ratio Low)	Life Loss Weighting Factor
User supplied	User	User	Equation 1	Table 1	Table 1	Equation 2
						Sum this column

Equation 1.

$$\frac{\text{Dist. D/S} - \text{Dist. D/S of First Notice}}{\text{10 miles per hour flood travel speed}} + \text{Breach Development Speed} - \text{Failure Mode Factor}$$

where the Breach Development Speed is .25 hour, .75 hour or 1.5 hours depending on the user's choice of fast, moderate or slow. The Failure Mode Factor is .375 (between 15 minutes in the day and 30 minutes at night) for Piping or Seismic failure modes, and .125 (between 0 minutes in the day and 15 minutes at night) for Hydrologic failure modes. If this equation results in .25 hour or less, the warning time category is "none". Between .25 hour and 1 hour, the category is "some". Greater than 1.5 hours is "adequate".

Equation 2.

Breach Development Speed: Instantaneous

Distance D/S 10 miles or less

$$((1 - \text{Dist. Downstream}/10) * .7 + .3) * \text{PAR} / 10$$

Distance D/S between 10 and 20 miles

$$((1-(\text{Dist. Downstream} - 10)/10) * .27 + .03) * \text{PAR} / 10$$

Distance D/S between 20 and 30 miles

$$((1-(\text{Dist. Downstream} - 20)/10) * .03) * \text{PAR} / 10$$

Distance D/S greater than 30 miles

0 * PAR

Equation 2. (Continued)

Breach Development Speed: Fast, Moderate, or Slow

No Warning

(PAR * (%PAR_Mod * (R_Ratio Mod * .32 + .03)
+ (1 - %PAR_Mod) * R_Ratio Low * .02)) / 10

Some Warning

No EAP

(PAR * (%PAR_Mod * (R_Ratio Mod * .07 + .01)
+ (1 - %PAR_Mod) * R_Ratio Low * .015)) / 10

Yes EAP

(PAR * (%PAR_Mod * (R_Ratio Mod * .035 + .005)
+ (1 - %PAR_Mod) * R_Ratio Low * .004)) / 10

Adequate Warning

No EAP

(PAR * (%PAR_Mod * (R_Ratio Mod * .055 + .005)
+ (1 - %PAR_Mod) * R_Ratio Low * .0006)) / 10

Yes EAP

(PAR * (%PAR_Mod * (R_Ratio Mod * .018 + .002)
+ (1 - %PAR_Mod) * R_Ratio Low * .0004)) / 10

Table 1. Life Loss Rate – Range Ratio

Breach Development Speed	Flood Severity		Warning	R_Ratio
Fast	Moderate (faster and deeper flow)		None	1.0
			Some	.9
			Adequate	.8
	Low (slower and shallower flow)	Close Proximity (<5 miles)	None	.9
			Some	.7
			Adequate	.6
		Farther Away (>5 miles)	None	.6
			Some	.4
			Adequate	.3
Moderate	Moderate (faster and deeper flow)		None	.8
			Some	.6
			Adequate	.5
	Low (slower and shallower flow)		None	.7
			Some	.5
			Adequate	.4
Slow	Moderate (faster and deeper flow)		None	.6
			Some	.4
			Adequate	.3
	Low (slower and shallower flow)		None	.5
			Some	.3
			Adequate	.1

Table 2. Life Loss Rate Ranges used in Equation 2

Flood Severity	Warning Time	Warning Message	Life Loss Rate (% of PAR)
High	None	None	.3 to 1.0
Medium (faster and deeper flow)	None	None	.03 to .35
	Some	Vague	.01 to .08
		Precise	.005 to .04
	Adequate	Vague	.005 to .06
		Precise	.002 to .02
Low (slower and shallower flow)	None	None	0 to .02
	Some	Vague	0 to .015
		Precise	0 to .004
	Adequate	Vague	0 to .0006
		Precise	0 to .0004